

Translator's Notes

There appears to be an error in Claim 11 of the German but I have translated it as it stands - on the assumption that the word "die" ("which") in the 3rd line refers back to the "Umfangswand (3a)") - i.e. as "which peripheral wall", even though the sentence as a whole does not appear to make sense.

Tubular piston for a piston engine and method
of manufacturing the same

5 The invention relates to a tubular piston and to a method
of manufacturing the same.

For various reasons, special requirements are imposed on a
tubular piston of the present kind. For one thing, it is a
10 mass product which is manufactured and distributed in large
numbers. The reason for this is not only that a piston
engine comprises a number of tubular pistons, but also that
a tubular piston is a typical wearing part which has to be
replaced after a certain service life. For these reasons,
15 there are special requirements as regards simple, rapid and
cost-effective manufacture.

In addition, the wear-resistance of the tubular piston
depends, among other things, on its weight, which should be
20 as low as possible in order to keep the centrifugal forces
which accelerate wear as low as possible when the tubular
piston is operating.

Another requirement consists in achieving a sturdy type of
25 construction which withstands both the pressure loads that
occur during operation and also bending loads and permits a
reduction in weight with the most thin-walled type of
construction possible. In this connection, it should be
mentioned that a long piston superficies reduces both the
30 surface pressure and also the pitching moment of the
tubular piston.

A tubular piston of the kind indicated in the pre-
characterising clause of Claim 1 is described in
35 DE 197 06 075 A1. This previously known tubular piston has
a hollow-cylindrical piston shaft which extends in one
axial direction from a tapered base section, while a joint
part extends from said base section in the other axial

direction in the form of a spherical head which is likewise of hollow construction. Passing through the entire tubular piston is a central pin which is a separate component which is pushed coaxially into said tubular piston in holes and
5 is fixed therein. The base section is constituted by an annular formed-in portion in the peripheral wall of a piston blank, said formed-in portion being pressed against the superficies of the preferably hollow pin. Formed-in at the front end of the tubular piston is an annular end wall
10 which emanates from the peripheral wall and is likewise formed against the superficies of the pin with its inner edge. The length of the pin is such that it passes through the tubular piston from the end wall as far as the rear end of the piston head, the peripheral wall constituting said
15 piston head being likewise formed-in against the superficies of the pin in an annular manner. The formed-in portion at the front and rear is produced with a forming-in force which is so great that the hollow peripheral wall of the pin is likewise formed-in along the lines of a waist.
20 As a result of this, the pin is axially fixed in the tubular piston. In this tubular piston, both the manufacture and also the warehousing for the pin which is to be incorporated as an additional component are expensive.

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A tubular piston which can be inferred from DE 199 38 046 A1 differs from the tubular piston described above through the fact that the base of the tubular piston is not constructed by a formed-in portion but is of solid
30 construction, the joint part is constituted by a dome-shaped joint recess which is open on the rear side, and the pin is formed onto the base part in the form of a hollow pin and extends in one piece towards the front end of the tubular piston where, once again, an end wall is formed-in
35 against its superficies. This known tubular piston is made sturdier through the fact that the pin is formed onto the

base section in one piece. The dome-shaped joint recess is formed into the rear side of the tubular piston by cutting.

The underlying object of the invention is to develop a
5 tubular piston and a method of manufacturing the same in such a way that said tubular piston is made sturdier while guaranteeing that it is guided in a satisfactory manner.

This object is achieved by means of the features of Claim 1
10 or Claim 9. Advantageous further developments are described in the appertaining subclaims.

Underlying the invention is the knowledge that, in a tubular piston which is described in DE 199 38 046 A1 and
15 has a rear joint part in the form of a dome-shaped recess, the superficieses of the tubular piston masks said joint part and therefore a long, large superficies or guide surface is available for the tubular piston, along with a reduction in the tilting moment which acts on the latter under operating
20 conditions, and this configuration should therefore be aimed at.

In the configuration according to the invention, the pin terminates in the region of the formed-in portion, which
25 makes it possible to construct the joint part in the form of a dome-shaped recess. This lengthens and enlarges the superficieses or guide surface of the tubular piston, under which circumstances the tilting moments that occur under operating conditions lie in the region of the guide surface
30 and a harmful effect on the tubular piston which said tilting moments presuppose is substantially reduced. Moreover, a sturdy type of construction is guaranteed, on the one hand by a strengthening of the structure which takes place when forming-in occurs, and on the other hand
35 by the fact that the formed-in portion and the pin are supported against one another, which makes the piston as a whole sturdier. Furthermore, in the configuration

according to the invention, the rear part of the formed-in portion constitutes a front surface region of the joint recess. As a result of this, the rear region of the formed-in portion is available as a joint surface belonging to the axial supporting system. A spherical head which is seated in the joint recess is therefore supported axially not only via the outer wall of the tubular piston but also via the pin, and this contributes to the sturdy type of construction aimed at.

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The method according to the invention described in Claim 9 permits simple, rapid and cost-effective manufacture of the tubular piston, the piston manufactured by the said method likewise having the advantages described above.

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A simple type of construction for the tubular piston is achieved if the pin extends in one piece from a front end wall of said tubular piston. In this case, the formed-in portion may be produced from a hollow-cylindrical piston blank which is prefabricated by cutting shaping or non-cutting shaping, for example by cold or hot extrusion.

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The underlying object of the invention is, furthermore, to further develop a tubular piston according to the pre-characterising clause of Claim 11, and a method according to the pre-characterising clause of Claim 14, in such a way that said tubular piston is given a long, large superficies or guide surface.

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This object is achieved by means of the features of Patent Claim 11 or 14. Advantageous further developments are described in appertaining subclaims.

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A long, large superficies or guide surface for the tubular piston is achieved through the fact that the formed-in portion is formed-in, not from a substantially hollow-cylindrical piston-prefabrication part, but from a

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prefabrication part with a prefabricated, external thickened portion of material, in such a way that said thickened portion is relocated from the outside towards the inside. As a result of this, it is possible to reduce a
5 cavity which is constituted on the outside by the formed-in portion, and to enlarge the superficies or guide surface of the tubular piston. The said formed-in portion is preferably produced in such a way that, after the forming-in operation, the superficies or guide surface of the
10 tubular piston extends in a continuous manner in the region of the formed-in portion. This can also be achieved precisely because of the fact that the formed-in portion is produced so as to be initially thicker, during the forming-in operation, than the outer dimensions of the tubular
15 piston, and the said thickened portion is adapted, in a final phase of operation, to the outer dimension of the tubular piston (for example by grinding), and this can happen before or after hardening at least of the surface layer of said tubular piston.

20 In the course of operation of an axial piston engine according to the invention, considerable heating-up occurs in the region of the piston which is moving to and fro, that is to say in the piston itself and in the cylinder
25 which guides it, which heating-up occurs because of the friction in the piston guides and leads, when the working pressure is high, to considerably high operating temperatures.

30 Also underlying the invention is the object of improving cooling in a tubular piston according to the pre-characterising clause of Claim 20.

This object is achieved by means of the features in Patent
35 Claim 20. Advantageous further developments of the invention are described in appertaining subclaims.

In its rear end region, the tubular piston according to Claim 20 has at least one duct which opens the cavity of the tubular piston towards the outside.

- 5 Underlying this configuration according to the invention is the knowledge that improved cooling can be achieved by an exchange of operating fluid which is located in the cavity of the tubular piston.
- 10 Although the exchange of operating fluid is relatively small when only one duct is present, centrifugal forces which improve the exchange of operating fluid in the tubular piston are nevertheless generated, under operating conditions, because of the movements of the pistons.
- 15 It is therefore advantageous to dispose, in the tubular piston, a number of ducts which are at a distance from one another which should be as large as possible as regards the exchange of operating fluid aimed at.
- 20 The at least one duct is to be disposed in such a way that its outer outlet aperture is open, at least at certain times during the operation of the piston, towards that cavity of the piston engine in which operating fluid or
- 25 leakage fluid is located at low pressure. The exchange of operating fluid through the duct or ducts is guaranteed, under operating conditions, by the Plantsch-type movements of the operating fluid located in the cavity. As a result of the Plantsch-type movements, the operating fluid passes
- 30 into all the regions of the cavity so that it is possible to proceed from an exchange of operating fluid which, although small, is nevertheless continuous, through the duct.
- 35 The subclaims contain features which contribute to making the piston and the joint connection sturdier and also to

cooling, and which lead to simple configurations which can be manufactured cost-effectively.

Advantageous configurations of the invention will be
5 explained in greater detail below with the aid of preferred exemplified embodiments and drawings. In the latter:

Figure 1 shows, in axial section, a tubular piston
according to the invention, in the form of a
10 finished part for a piston;

Figure 2 shows a piston module which comprises a tubular
piston according to the invention and a sliding
shoe which is connected to the latter in an
15 articulated manner;

Figure 3 shows a blank for a tubular piston according to
the invention, in a first stage of
prefabrication;
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Figure 4 shows a blank for a tubular piston according to
the invention, in a first stage of prefabrication
and in a modified configuration;

25 Figure 5 shows a prefabrication part for a piston, in a
second stage of prefabrication;

Figure 6 shows a prefabrication part for a piston, in a
third stage of prefabrication;
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Figure 7 shows a prefabrication part for a piston, in a
second stage of prefabrication and in a modified
configuration;

35 Figure 8 shows a prefabrication part for a piston, in the
third stage of prefabrication and in a modified
configuration;

Figure 9 shows a prefabrication part for a piston, in the third stage of prefabrication and in a configuration which has been modified further;

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Figure 10 shows the prefabrication part for a piston, in the third stage of prefabrication and in a configuration which has been modified further;

10 Figure 11 shows the prefabrication part for a piston, in the third stage of prefabrication and in a configuration which has been modified further; and

15 Figure 12 shows the prefabrication part for a piston, in the third stage of prefabrication and in a configuration which has been modified further.

The tubular piston, which is designated by 1, consists of a
 20 base section 2 from which a piston shaft 3 extends forwards in one axial direction and a joint part 4a extends rearwards in the other axial direction, which joint part is part of a ball-joint connection 4 which connects the piston 1, in a universally swivellable manner, to a sliding shoe 5
 25 which has a corresponding joint part 4b. In all the exemplified embodiments, the joint part 4a on the piston 1 is constituted by a dome-shaped joint recess 4c into which a spherical head 4d on the sliding shoe 5 fits with little clearance of motion. The joint recess 4c is disposed at a
 30 depth such that its free edge 4e extends beyond the appertaining equatorial plane 4f and is formed-in in such a way that it engages, in a form-locking manner, behind the spherical head 4d with little clearance of motion. For this purpose, the free edge 4e can be compressed, as shown
 35 in Figure 2, with its material in the cold or heated-up condition. In order to facilitate the compressing operation, the wall thickness of the free edge 4e may be

tapered outwards in the region protruding beyond the equatorial plane 4f, and this can likewise be inferred from Figure 2.

5 The sliding shoe 5 also has a base plate 5a which carries the spherical head 4d and whose flat base surface 5b constitutes a sliding surface with the aid of which the tubular piston 1 is supported, in the condition in which it is mounted in an axial piston engine, on a swash plate or
10 wobble plate whose oblique surface is illustrated by a line 6. Under these circumstances, the piston shaft 3 is mounted so as to be displaceable to and fro longitudinally in a piston bore 7 belonging to a cylinder 8 which may be mounted in a rotatable or non-rotatable manner in a
15 housing, not represented, belonging to the axial piston engine.

The cavity of the piston shaft 3, which cavity is designated by 9, is occluded at the rear end by the base
20 section 2, on the periphery by a hollow-cylindrical peripheral wall 3a, and at the front end by an end wall 3b. The tubular piston 1 has a central pin 11 which extends from the end wall 3b as far as the base section 2, is supported axially and radially on the latter, and thereby
25 makes the tubular piston 1 as a whole, and the end wall 3b, sturdier axially.

In the present exemplified embodiments, the pin 11 extends rearwards from the end wall 3b in one piece, right into the
30 rear end region of the base section 2, as will be described below. A duct 12 extends in an axially continuous manner through the pin 11, a throttle 12a being disposed in said duct 12.

35 The base section 2 has a formed-in portion 14 which, in the exemplified embodiments according to Figures 1 to 6, is constituted by the annular forming-in of an axial section

3c of the peripheral wall 3a and, in the exemplified
embodiments according to Figures 7 to 12, is constituted by
the annular forming-in of an axial peripheral-wall section
3c which has an annular thickened portion of material 3d on
5 the outside. In each case, the formed-in portion 14 is
formed-in to an extent such that it presses radially
inwards against the superficies 11a of the pin 11. As a
result of this, the cavity 9 is occluded in a leakproof
manner at the rear end. The formed-in portion 14
10 constitutes, with its rear stepped face 14a, at least part
of the surface 4c of the recess.

The formed-in portion 14 according to Figures 1 to 6 can be
formed-in by rotary swaging or rotary rolling with the aid
15 of shaping tools 15a, 15b which are indicated in outline in
Figure 1 and each have a superficies 15c which is rounded
convexly in cross-section, the deforming pressure, which is
directed radially inwards, being exerted on the superficies
of the tubular piston 1. The convexly rounded inner
20 shoulder of material 3e, which presses radially inwards
against the pin 11, is formed in the process.

In the exemplified embodiment according to Figure 7 and the
subsequent figures, the formed-in portion 14 is formed-in
25 radially inwards by cylindrical shaping tools 15d, 15e,
under which circumstances the thickened portion of material
3d is completely formed-in and the annular inner shoulder
of material 3e, which is likewise rounded convexly in
cross-section and presses against the superficies 11a of
30 the pin 11, is constructed. The volume of the thickened
portion of material 3d approximately corresponds to the
volume of the shoulder of material 3e.

For reasons connected with an advantageous flow of material
35 during the forming-in operation, it is advantageous to
construct the thickened portion of material 3d with lateral
surfaces 3f of the ring which converge radially outwards.

The angle of inclination of these lateral surfaces 3f of the ring may, for example, be about 45°.

In the case of all the exemplified embodiments, it is
5 advantageous to produce the formed-in portion 14 with a compressive force which is directed radially inwards and is of a magnitude such that said formed-in portion 14 not only presses against the superficies 11a of the pin 11, but also produces, in the superficies 11a of said pin, a formed-in
10 portion 11b in the form of an annular groove which may, for example, be rounded. This provides not only a clamping connection between the formed-in portion 14 and the pin 11, but a connection which operates in a form-locking manner and is capable of transmitting forces which are directed
15 axially to a considerable extent, or of absorbing loads.

In order to have sufficient forces of resistance, which are directed radially outwards, in the pin 11, particularly in the case of a reinforced formed-in portion 14b of this
20 kind, it is also advantageous to construct the throttle 13 with an increased wall thickness for the pin in the region of the formed-in portion 14, so that said pin 11 is able to put up a greater force of opposition, which is directed radially outwards, to the formed-in portion 14, and the
25 latter can be produced with greater pressure contact of the material, as a result of which the reciprocal support and the sealing are improved.

The tubular piston 1 which has been described so far is a
30 precision part, the superficies 3g of which is a locating surface and guiding surface for the longitudinal guidance of said tubular piston 1. This also applies to the inner surface 4g of the joint recess 4c, at least in the region of its rounded portion. It is therefore advantageous to
35 construct the superficies 3g and the inner surface 4g, as regards their finished shape and size, with an oversize x which is brought to its final fitting size by a finishing

operation, for example by turning, milling or grinding.
The oversizes x are represented, for example in Figures 6 and 8 and subsequent figures.

- 5 A tubular piston which has been prefabricated to this extent is represented in Figure 6 as a prefabrication part for a piston. In this connection, the prefabrication can take place in a number of stages and by different methods of production, as is shown, on the one hand, in Figures 3 and 5 and, on the other, in Figures 4 and 5.

In the exemplified embodiment according to Figure 3, there is prefabricated, in a first stage of prefabrication, a blank 16a which differs from the prefabrication part 17a
15 belonging to the second stage of prefabrication particularly in having a small axial length L_1 which is substantially smaller than the length L_2 of the prefabrication part 17a belonging to the second stage of prefabrication. The blank 16a may be produced by cutting,
20 for example by cutting a bar-shaped semi-finished product to length. Said blank 16a is deformed in a non-cutting manner to form the prefabrication part 17a, by extrusion in an extruding tool which is not represented. The extruding operation may take place in the cold condition (for example
25 at room temperature) or in the hot condition (for example, heated up to a favourable flow temperature). The peripheral wall 3a and the pin 11 are extruded in the extruding operation, in the course of which the end wall 3b is constructed. The extruding operation takes place in
30 such a way that the pin 11 is shorter than the peripheral wall 3a and its rear free end is therefore at an axial distance a from the rear free end of the peripheral wall 3a. Said distance a approximately corresponds to the radius r of the joint recess 4c plus the length L_3 by which
35 the section 3h of the peripheral wall projects rearwards beyond the equatorial plane 4f.

Alternatively, the prefabrication part 17a may be produced from a blank 16b according to Figure 4 by cutting, for example by boring an annular hole. This cutting-type production results, at least on the superficies of the pin 11 and on the inner superficies of the peripheral wall 3a, in furrows which extend in the peripheral direction and which can impair the strength of the finished tubular piston 1. On the other hand, the pin 11 and the peripheral wall 3a are strengthened and made sturdier during extrusion, in the course of which fibres of material which extend longitudinally and which further increase the strength of the material are also constructed.

In the exemplified embodiment according to Figure 4, the length L4 of the blank 16d approximately corresponds to the length L2 of the prefabrication part 17a, which is represented on an enlarged scale.

The prefabrication of the modified prefabrication part 17b according to Figure 7 may take place in the manner described above from blanks according to Figures 3 and 4, likewise by extrusion or by cutting-type production. In order to avoid repetition and to shorten the description, the reader is therefore referred to that part of the description.

In the ongoing production of the prefabrication part 17a according to Figure 5 in the third stage of prefabrication to form the prefabrication part 17c according to Figure 6, or in the ongoing production of the prefabrication part 17b according to Figure 7 in the third stage of prefabrication to form the prefabrication part 17d according to Figure 8, a formed-in portion 14 is formed-in in each case, and this takes place by means of the rounded shaping and counter-shaping tools 15a, 15b according to Figure 1 or the approximately cylindrical shaping and counter-shaping tools 15d, 15e according to Figure 7.

The volume of the thickened portion of material 3d is predetermined to be of a size such that, after the forming-in of the formed-in portion 14, the prefabrication part 17d (Figure 8) is approximately cylindrical, that is to say including the oversize x.

The formed-in portion 14 is formed in, in each case, in such a way that it borders the joint recess 4c with its rear stepped surface 14a, that is to say, taking into account the oversize x. In a comparable manner, the pin 11 may also be prefabricated with a distance a such that said pin likewise borders the joint recess 4c on the front side of the latter, that is to say, likewise taking into account the oversize x. Alternatively, however, the distance a may also be of larger dimensions, so that although the pin 11 borders the joint recess 4c on the front side, it nevertheless does not constitute the latter's spherical bearing surface but is at an axial distance, not represented, from the said spherical bearing surface (surface finally constructed). This is likewise possible because the inner shoulder of material on the formed-in portion 14 constitutes a sufficiently large bearing surface for the joint recess 4c, so that the end face of the pin 11 can protrude forward from the said finished bearing surface.

In a further stage of prefabrication, the superficies 3g and the pivoting or inner surface 4g of the joint recess 4c, and optionally the end face of the end wall 3b too, may be machined to final size by a cutting method, and this may take place, for example, by milling or grinding. In this connection, hardening of the material of the tubular piston 1, for example surface-hardening, preferably by nitriding, may take place before or after this fine-machining to final size.

After that, the finished piston part 17e according to Figure 1 which has been produced so far can be put together with the sliding shoe 5 and connected in a form-locking manner by the forming-in of the peripheral wall section 3h, as a result of which the piston module according to Figure 2 is formed.

The manufacturing measures mentioned above also apply in a corresponding manner to the exemplified embodiment according to Figure 8.

Figures 9 to 11 show other production measures which serve to make sturdier and/or seal the connection between the formed-in portion 14 and the pin 11.

In the exemplified embodiment according to Figure 9, the pin 11 is welded to the formed-in portion 14. The welding seam 21 may lie in the region of the junction between the pin 11 and the formed-in portion 14 and be produced before or after machining to final size has been carried out.

In the exemplified embodiment according to Figure 10, the pin 11 and the formed-in portion 14 are soldered to one another, and this may take place at the stepped surface on the front side (see Figure 10) or at the stepped surface on the rear side. If soldering 22 is carried out on the front side, a solder which is required for soldering purposes is to be fed into the cavity 9 prior to the forming-in of the formed-in portion 14.

In the exemplified embodiment according to Figure 11, the junction which exists between the pin 11 and the formed-in portion 14 is sealed by means of a seal 19. Said seal 19 is preferably constituted by a sealing ring 19a which is seated in an annular groove 19b and interacts in a sealing manner with the annular surface lying opposite. Said annular groove 19b may be disposed in the superficies 11a

of the pin 11 or in the inner superficies of the formed-in portion 14.

The exemplified embodiment according to Figure 12 shows the following special configuration, which may be constructed in a tubular piston 10 which has been described above, or even in tubular pistons having a different type of construction.

10 In this configuration, the cavity 9 is connected to the environment of the tubular piston through a duct 21 whose outer outlet aperture 22 is located in the rear end region of said tubular piston 1. The outlet aperture 22 may be positioned in such a way that, when a piston engine, in particular an axial piston engine, having the tubular piston 1 is operating, said aperture passes out of the cylinder 8 and into the cavity of the housing of said piston machine at least temporarily under stroke-type operating conditions. This is the case when the outlet aperture 22 is located temporarily, under stroke-type operating conditions, in the piston guide, in which it is substantially masked by the piston superficies of the piston bore 7 and, in the region of the rear dead centre of the piston stroke, is in communication with the cavity of the housing, for example projects rearwards out of the piston bore 7.

The advantage of this configuration of the tubular piston 1, which is independent of the exemplified embodiments described above, consists in the fact that an exchange takes place, through the duct 21, between the hydraulic fluid located in the cavity 9 of the tubular piston 1 and the fluid in the cavity of the housing. As a result of this, the cooling of the tubular piston is improved.

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One or more ducts 21 disposed in a manner distributed over the periphery may be provided, as is represented in outline

in Figure 12 by chain-dotted lines. As a result of this, the exchange of fluid is improved and increased. If, when the tubular piston 1 is operating, there are located, in a manner lying radially on the inside and radially on the outside, at least one duct 21 in each case, the exchange of fluid can take place as a result of a conveying action which is brought about by centrifugal force and which accelerates the exchange of fluid.

- 10 In the exemplified embodiment, the at least one outer outlet aperture 22 is located at a distance c from the rear side of the tubular piston 1 which is smaller than half the length L_5 of the piston and preferably about $1/5$ of said length L_5 .